

ERROR CORRECTION, CONTROL SYSTEMS AND FUZZY LOGIC

By Earl B. Smith

Abstract

This paper will be a discussion on dealing with errors. While error correction and communication is important when dealing with spacecraft vehicles, the issue of control system design is also important. There will be certain commands that one wants a motion device to execute. An adequate control system will be necessary to make sure that the instruments and devices will receive the necessary commands. As it will be discussed later, the actual value will not always be equal to the intended or desired value. Hence, an adequate controller will be necessary so that the gap between the two values will be closed.

Introduction

The point of this research was to find a suitable link between control systems design and error correction and detection. This was sought as to basically enhance both techniques. One reason of thinking was that if the error correction algorithm was made more efficient that it would make it easier for the control system or systems to function. Also, if the control system is stable, the thinking is that the pressure would be taken off of the error detection and correction, parity, and checksum techniques in order for them to function at its highest capability.

It should be stated that error correction is necessary to combat the errors caused by radiation, regardless of the control system. It is necessary so that as many errors as possible are corrected. So a control system should not be used in place of error

correction and detection. The same or similar things could be said of a control system being replaced.

So the paper is set up as follows. The paper primary focuses on control systems as oppose to error correction and detection, parity, and checksums. This is done because of the author primary has a background in control systems, and control systems do deal with error.

The next section briefly discusses control systems and control system design. The discussion primary centers on the error that is obtained in a closed loop system. The use of the controller is mentioned to state, a little, on how the error, the difference between the actual and desired values, is reduced.

In the conclusion and recommendations, findings and ideas on future work are presented.

Error, Correction and Detection, Control Systems and Fuzzy Logic

In his example of using one's eyes, Pretzel in [1] stated how the eyes are able to use experience to find out or understand the correct image that is being seen. Then the brain uses various techniques to sort out the possible conclusions.

He also discusses another method of correcting error where the language restrictions are used as oppose to experience.

Pless in [2] defined error correcting as "the art of adding redundancy efficiency so that most messages, if distorted, can be correctly decoded." As stated in various works, the transmission of data that is redundant is compared for agreement, or the lack thereof, purposes [1-10].

Yet, when the issue of error is discussed in control systems, it has to do with the error or actuating signal [11-15]. Its values are obtained from a closed loop transfer function where it is the input into the controller. Consider in figure one the variables R , C , and E . Let R be the reference or desired input. Let C the actual or controlled output. And let E the error or actuating signal. Also, let there be unity feedback and no gain at the input as it is shown in Figure One. Then the error, E , is equal to $C-R$ [11-15]. Any value of E not equal to zero may require some kind of compensator, lead or lag, to be added to the controller [11, 12]. With the changes in the controller, there may be increased stability, more robustness, and a bigger chance of the actual value reaching the desired value.

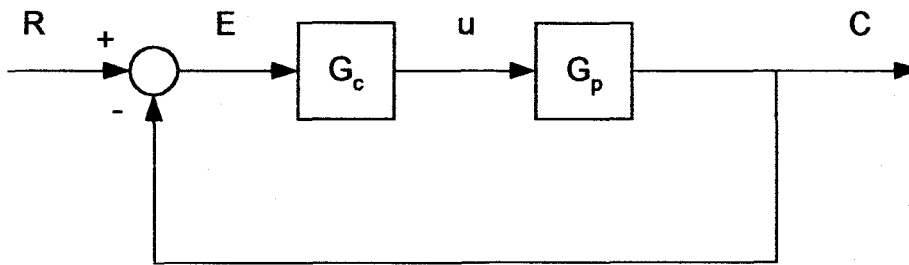


Figure One. Block Diagram with unity feedback.

If there is a gain at the input as shown in Figure Two, it is called the filter gain. Non-unity feedback is referred to as the feedback compensator. Then the error, E or $E(s)$, could be equal to $HC-G_fR$ where H is for the feedback compensation and G_f is the input filter [11, 12, 15].

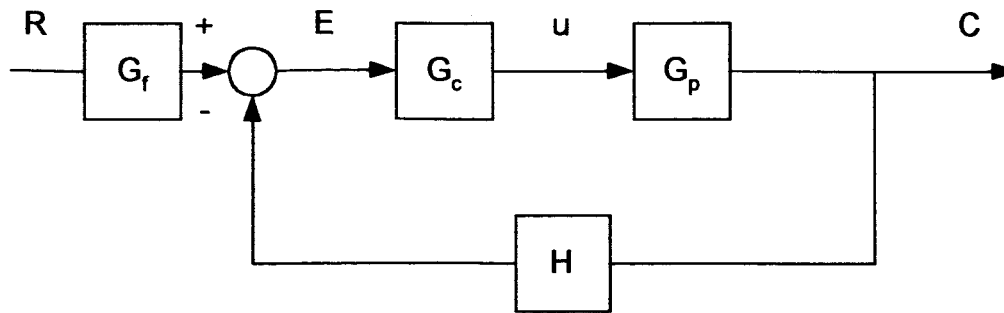


Figure Two. Block Diagram with non-unity feedback and filter input.

Some issues that deal with control systems are the temperature inside, temperature of other compartments, the speed, and direction. In physics terms speed with direction can be combined for the velocity, a vector. Some of this will be discussed later.

Also, it is desirable to make sure that the control system is very stable, robust and have little steady-state error. Regardless the types of control systems, this could be done by a variety of ways. Those ways include using the linguistics of a fuzzy logic control system, designing a suitable compensator or comparator, and adequate feedback [11-15].

Control systems can be either continuous, discrete or both [12]. Robotic systems, autonomous, pre-programmed or teleoperated, can contain control systems that are continuous and discrete. As Stadler stated in [16] logic gates and binary concepts are important in understanding encoders and decoders. Encoders and decoders are an integral part of the electronics of a robotic system, especially when it comes to sending messages. This includes the operational amplifiers, semiconductor devices, solid-state devices, and logic circuits.

Needless to say, the operation of the sensors is paramount to how the robotic systems take commands and function [17]. When the sensor takes in the analog value from the medium or the outside, the quantity (or image) that the observer accepts may not

be exactly the same value as the analog value [16]. The analog signal, or value, that comes in from the medium, or outside, is detected and later manipulated and measured for the observer [16]. Or as Jones and Flynn stated in [18], the input from the sensors are gathered and interpolated. Then the world model is developed, and the planning and execution comes. Yet due to errors and uncertainty, we are not able to 100% completely sense what we want to measure [16, 18].

Some sensors that are used on robots are ultrasonic, tactical, vision and force sensors [16-18]. The expenses to get the best and/or most accurate ones can get very high [15]. However, in the case of ultrasonic sensors, very expensive sensors are not absolutely necessary. For example, crude ultrasonic sensors will not always get the exact image. Yet, due to a soft computing paradigm like fuzzy logic, Tunstel et al explained how expensive and accurate sensors are not absolutely necessary [19, 20]. This is because fuzzy logic uses imprecision and uncertainty in order to get to a conclusion [13, 14, 19, 20].

Hence, a fuzzy logic controller can use linguistic variables in its execution [13, 14, 19, 20]. The fuzzy logic controller uses IF-THEN statements in testing for a change in error. In the IF-THEN statement, the IF part is the antecedent while the THEN part is the consequent. As stated earlier the output of the controller is generally the input to the plant.

Let's consider some problems that may exist due to computer errors.

1. Vehicle is not in its proper orbit,
2. Vehicle is not going at the desired speed,
3. Vehicle is not at the proper thrust in the beginning,

4. Less than adequate or poor communication between mission control and outer space,
5. Robotic arm does not function properly (angle and speed),
6. Improper or bad landing,
7. Temperature on the inside is not at its desired value,
8. Vehicle is not going in the proper direction,
9. Poor circulation of air inside the vehicle,
10. Entry into Earth's atmosphere will be a concern,
11. Cameras or vision sensors do not rotate (to the intended image) or function properly,
12. Cameras do not get the proper image for the crew to see,
13. Engine temperature is not at its proper value,
14. Sensors that give the speed, inside temperature, coordinates, engine temperature, etc. do not function properly.

Some of these items are related like numbers seven, nine and 14. In essence it is possible to partially fix some other problems while one is being fixed. It depends on the relation of one problem to another.

Let's take a brief look at number seven. For instance, someone sets the inside temperature, where the astronauts are, to (Let's say.) 78°F. Let's say that the controller is a fuzzy based one. Let the membership functions (a graphical representation of a fuzzy set) for measured temperature are COLD, COOL, WARM, and HOT. Let the temperature of 78°F be considered WARM. Any actual temperature that is above or below, especially if the temperature is significantly above or below 78 degrees, would

cause the controller to act to where the actual output, or temperature, would become more in line with the desired output, or temperature. So if the temperature's actual output was at 68, a human operator could come up with the following IF-THEN statement in their mind: IF ACTUAL TEMP is COOL, THEN AIR RELEASED is WARM. But the controller could have a command such as: IF error is "positive" AND change in error is "positive" THEN change in input is "positive." For more on fuzzy logic control see the works by Ross in [13] and Langari and Yen in [14].

The previous paragraph was an example on how the fuzzy controller (as stated before) corrects the error that exists in the closed loop transfer function. For instance, if a vehicle is moving in a direction too far to the left, there are commands, especially in fuzzy logic control, that can steer towards a more rightward direction. Consider this. Let's say that the steering is set up in angles. Let a direction of zero be directly in front, the negative angles be to the left, and the positive angles be to the right. If the vehicle is suppose to move in a direction that is straight ahead but is moving to the left, then a command can state that the vehicle should turn in a rightward direction, or a positive angle direction. Hence, the vehicle would be moving in the correct direction.

Conclusions and Recommendations

A strong or closed link between error correction and control systems was not determined in this research. In his dissertation in [21], Tsao applied the use of fuzzy sets in order to make fuzzy the observations for wind and current. Tsao also talked about error detection modules looking for inconsistencies between something modeled and observed. But the object that was modeled and observed had to do with marine oil spills.

In robotics control and sensing are affected by the inaccuracy and errors. Also, there is uncertainty about the environment's geometry, which Bruce calls the model error in [22]. He also talks about Error Detection and Recovery (EDR) strategy is, loosely interpreted, when a strategy gets to a reachable goal that is recognized but yet issues failure. However, as was stated earlier and by Tunstel and others, soft computing paradigms like fuzzy logic and neural networks have been used in robotics to overcome the uncertainty and imprecision, especially of what is being sensed, that may occur through the sensors' readings [19, 20].

Recommendations

As was stated before, the desire was to see how fuzzy logic control could directly enhance error correction and detection and vice versa. But despite the lack of findings, there are some things that one could consider.

1. One should keep a stable control system for obvious reasons. An unstable control system could cause system malfunctions, bad data, and very inaccurate performance by the system [11-15]. Consider this. If the control system for the temperature is not stable, the chances would be very low that one could get the accurate readings. In other words the reading of the output value will not be accurate. And the operator would not know what the actual temperature is.
2. As was stated earlier, use of an adequate control system, especially with the use of fuzzy logic, may allow one to use inexpensive sensors [19, 20]. With the use of fuzzy logic, one does not have to worry too much about the imprecision and uncertainty of the images sensed by the sensors. Since fuzzy logic uses approximation and not the absolute analysis of crisp or classical logic,

imprecision can actually be beneficial in stability or giving commands. (This makes fuzzy logic more flexible.) The reduce cost in sensors should help in reducing the cost in the overall equipment.

3. Included with the cost, one should see if the type of control system will have an affect on any other system or algorithm. This includes error correction and detection, parity and checksum. While fuzzy systems may allow for inexpensive sensors, the type of controller and algorithm can influence the hardware. What effect will the type of hardware have on error correction? If the effect is negative, how will one have to change the control system? Or will there be an effect at all? Will any other system have to be changed because of the controller or control system? These are some questions that may have to be answered.
4. In relation to numbers two and three, the issues of the controller and hardware can be related. Problems that can arise are the rewiring and replacing of the electronics. Other issues dealing with analog controllers can be difficult, clumsy and inexpensive. The availability of the circuit is a concern as well. But Jacob stated in [15] that digital control can solve these problems with less cost while introducing the microprocessor, single-chip microprocessor and intelligence in the manufacturing process. Ross in [14] and Yen and Langari in [13] showed that intensive mathematics are not always, if ever, needed while using fuzzy logic. In essence the choice of the type of controller is important when it comes to the cost and hardware as well at the stability of the system. Some of the questions in number three can apply hear as well.

These recommendations for the control systems were basically stated in order to reduce the chances of system malfunction, damaged or lost data or worse life threatening situations [3]. There were stated so that the cost of operation and the parts are reduced. While there may not be the strong link between error correction techniques and control system, fuzzy logic and fuzzy logic design, it is hoped that the upkeep of the control systems will not adversely affect the other systems, techniques or algorithms.

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